SECTION IV. THEORY OF OPERATION

11.4.1 PRINCIPLES OF OPERATION

The ASOS freezing rain sensor uses an ultrasonic axially vibrating probe to detect the presence of icing conditions. This sensing probe is a nickel alloy tube mounted in the strut at its midpoint with 1 inch (25.4mm) exposed to the atmosphere. This tube exhibits magnetostrictive properties and expands and relaxes under the influence of a variable magnetic field. A magnetic bias field is provided by a magnet mounted inside the strut and modulated by a drive coil surrounding the lower half of the tube. A magnetostrictive oscillator (MSO) circuit (figure 11.4.1) is created by the addition of a pickup coil and operational amplifier. The ultrasonic axial movement of the tube resulting from the activation of the drive coil causes a current to be induced in the pickup coil. The current from the pickup coil drives the operational amplifier, which provides the signal for the drive coil. The oscillation frequency of the circuit is determined by the natural resonant frequency of the sensor tube, which is tuned to approximately 40,000 hertz. As the ice detector encounters an icing environment, ice collects on the sensing probe. The added mass of accreted ice causes the frequency of the sensing probe to decrease in accordance with the laws of classical mechanics. A 0.02-inch (0.5mm) thickness of ice on the probe causes the operating frequency of the probe to decrease by approximately 133 hertz. The ice detector control circuitry utilizes a microprocessor to monitor probe frequency when instructed by ASOS. The ice detector deices itself through internal heating elements in both the strut and probe. After the ice detector is deiced, the sensing probe cools quickly and is ready to sense ice formation again.

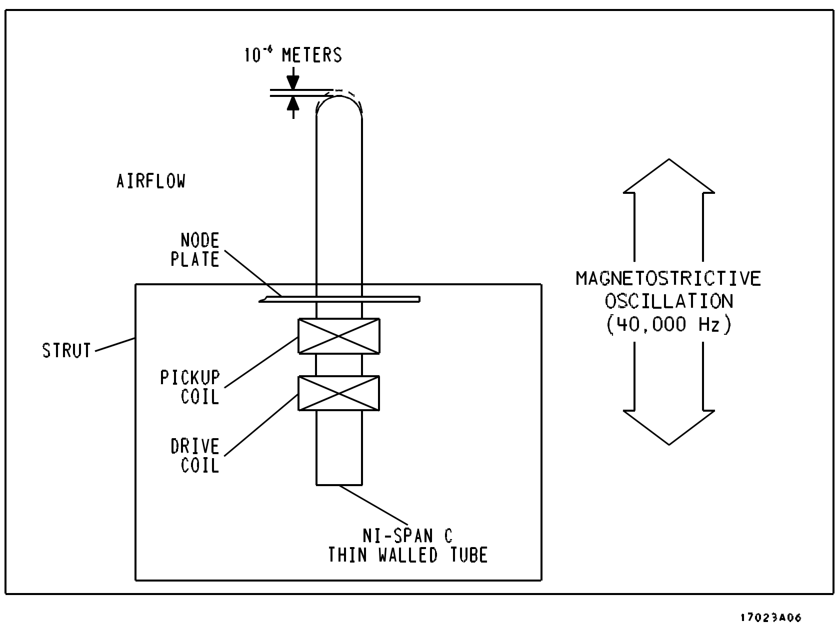

Figure 11.4.1. Magnetostrictive Oscillator Circuit

11.4.1.1 **Probe Assembly**. The probe assembly consists of the probe (sensing element), the strut, and the deice collar. The strut contains pickup and drive coils, cartridge heaters, a magnet, and a retaining spring. The probe assembly minimizes the flat area around the probe and contains radial grooves machined in the conical portion of the strut. This design prevents water droplets from collecting around the probe nodal area in still air conditions. The deice collar aids in breaking up ice that may form on the heat sink (refer to paragraph 11.4.1.3). The sensor water shedding ability eliminates false signals due to water refreezing at the base when the atmosphere does not contain liquid water to actually form ice on the probe element.

11.4.1.2 **Heaters**. Deicing is accomplished using a heater brazed in the interior of the probe. A pair of cartridge heaters deice the strut. During deicing, the maximum power drain is 400 watts. The deicing system is capable of completely melting approximately 3.8mm of ice on the strut and probe within 30 seconds at -20°C.

11.4.1.3 **Heat Sink**. The heat sink consists of a 4.5-pound (2.05 kilograms) mass of anodized 6061 aluminum that separates the electronics and probe strut. The heat sink provides heat dissipation for the probe and strut during deicing. The purpose of the heat sink is to achieve a recovery time (defined as the time required for the sensor to revert to ambient temperature after being deiced). The heat sink thermally isolates the sensing element from the electronics heat, which allows accurate measurement at temperatures at or close to 0°C.

11.4.2 **SIMPLIFIED BLOCK DIAGRAM DESCRIPTION**

Figure 11.4.2 provides a simplified block diagram of the freezing rain sensor. All circuitry is contained on Electronics Processor Board A1A2 or in Probe Assembly A1A1.

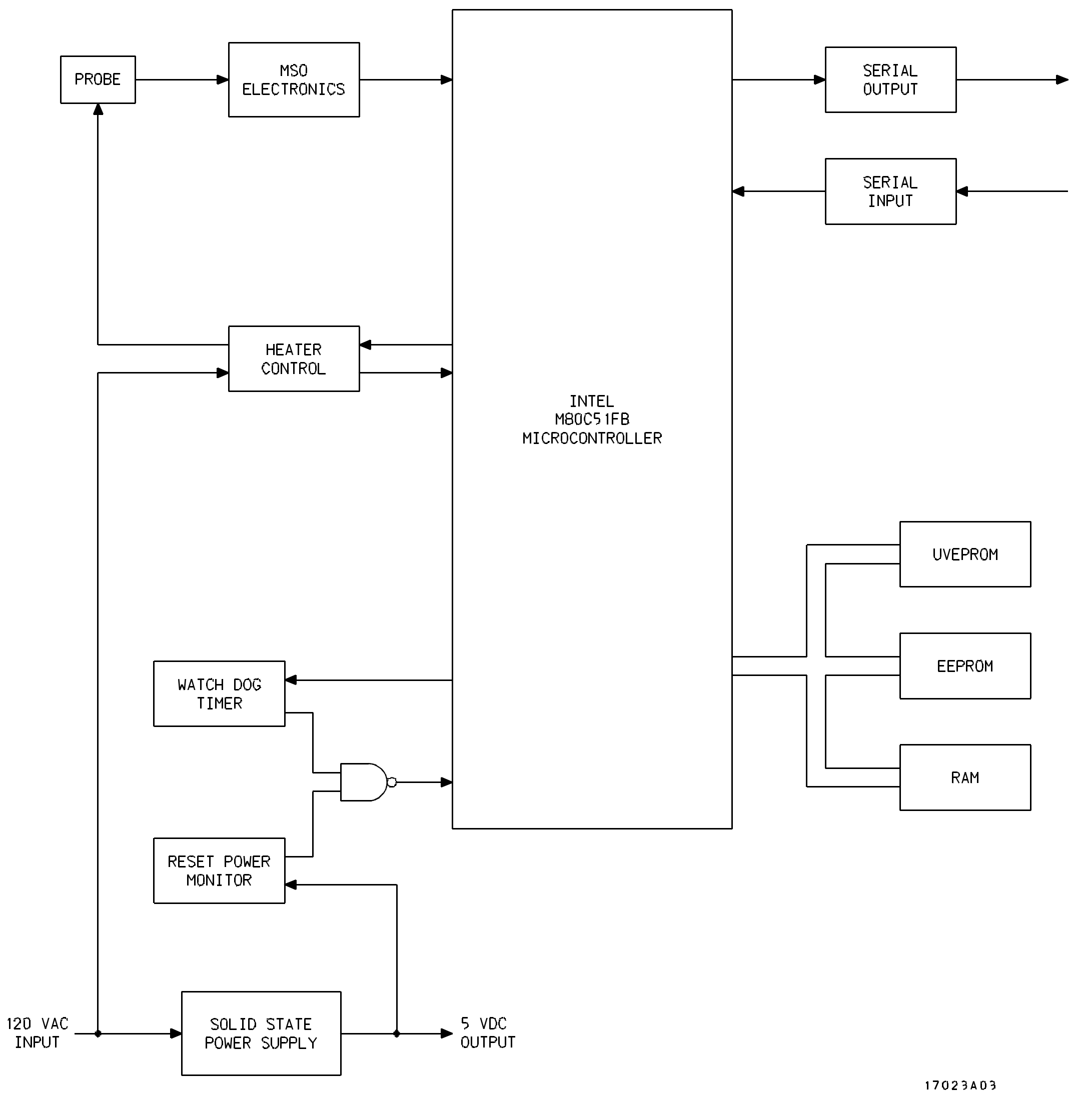

Figure 11.4.2. Freezing Rain Sensor Simplified Block Diagram

11.4.2.1 **Electrical Input Requirements**. The sensor utilizes 115vac (103.5 to 126.5 vrms), 55- to 65-hertz input power. Normal operation continues for power interruptions of less than 10 milliseconds. Power interruptions greater than 10 milliseconds cause the sensor to go into a reset condition. Under this condition, the sensor resumes operation automatically after power is reapplied and the power up test sequence completes. Terminals 1 and 2 and terminals 4 and 5 are on separate circuit breakers, respectively. The ac power terminal connections for the sensor are as follows:

Terminal	Function
1	115 vac, hot, electronics
2	115 vac, neutral, electronics
3	Chassis ground (model 0872C2 only)
4	115 vac, hot, heater
5	115 vac, neutral, heater
E1	Chassis ground(model 0872C3 only)

11.4.2.2 **Communications Link**. The freezing rain sensor communicates with the DCP via fiberoptic cables. In the sensor, Fiberoptic Module A1A2A1 provides the interface between optical signals of the DCP and the RS-232 electrical signals applied to the sensor Electronics Processor board. The DCP polls the sensor for data every 60 seconds. The sensor responds with the requested ice condition and self-test status.

11.4.2.3 **Microcontroller**. The sensor uses an M80C51FB 8-bit microcontroller. This chip contains an internal RS-232 interface, which greatly simplifies the interface to the DCP. The unit's firmware is contained on a separate ultraviolet erasable programmable read only memory (UVEPROM) chip mounted on a socket. This permits the unit's software to be easily changed in the field by removing the UVEPROM chip from its socket and replacing it with a chip containing the new program. An electrically erasable programmable read only memory (EEPROM) is used to store data and tables used in computation. The unit also features a nonvolatile read and write memory (RAM) chip that permits any detected failure codes to be stored in the unit. A failed unit can be brought back to a repair facility and the failure code read to determine how the unit failed.

11.4.2.4 **Watchdog Timer/Reset Power Monitor**. A single chip combines the function of watchdog timer and power monitor. The purpose of the watchdog timer is to monitor the operation of the microcontroller. The microcontroller must output a pulse into the watchdog timer approximately every second or the watchdog timer causes the microcontroller to go into a reset condition, which reinitializes the microcontroller. The power monitor circuit causes the microcontroller to reset any time that the voltage drops below 4.65 vdc, which is the lower operational voltage for the memory circuits. Any time that the voltage drops below 4.25 vdc, it is possible for the memory circuits to lose memory. The power monitor maintains the microcontroller in a reset condition until the supply voltage is above 4.65 vdc.

11.4.2.5 **Heater Control**. The heater control circuit consists of a mechanical relay with a solid-state interface circuit to the microcontroller. When ice has accreted on the probe to a predetermined thickness (typically 2.0mm), ASOS instructs the heater circuit to furnish 115 vac to the heaters in the probe and strut, causing the ice to melt. A mechanical relay is used instead of a solid state relay to avoid any leakage current that might flow through the heater circuit when the relay is in a deenergized state. A leakage current would cause some heating of the probe, which would have an adverse effect on freezing rain detection, especially around 0°C ambient air temperature. There is a feedback circuit to the microcontroller to ensure that the relay is operating properly.

11.4.3 **COMMAND DESCRIPTION**

The freezing rain sensor responds to commands issued by the DCP during normal operation and by the technician during maintenance. The following paragraphs describe these commands.

11.4.3.1 **Quick Reference**. There are four different requests that the freezing rain sensor responds to over its RS-232 communications link. These commands are summarized as follows:

Command	Description
Z1	Send routine data
Z3XX	Perform deice cycle for "XX" seconds (minimum 01 second, maximum 60)
Z4	Perform extended diagnostics
F5	Field calibration

11.4.3.2 **Power Interruptions**. After a power interruption (greater than 50 milliseconds), the freezing rain sensor takes 30 seconds to initialize and an additional 15 seconds to calculate an averaged frequency for output. If a Z1 command is issued within 30 seconds of power-on, the sensor does not respond. If the sensor fails to respond to any Z command, an additional 30 seconds is required before the command can be reissued.

11.4.3.3 **Z1 Request (Send Routine Data)**. The Z1 command is the request sent from the DCP once per minute to obtain sensor data. The sensor responds to the Z1 command with the sensor frequency normalized over a 1-minute period. The sensor provides status (pass/fail/deice), a failure code, and a checksum value. Figure 11.4.3 illustrates the format of the sensor response. The Z1 request should not be issued more often than once per minute. If it is, the sensor response will be unchanged from the previous response until the 1-minute normalization period has passed.

If a BIT failure is detected (F in status byte), the sensor does not respond correctly to Z1 or Z3 commands. The sensor will, however, respond to Z4 and F5 commands.

If the Z1 request is issued within 5 minutes of a deice cycle, the sensor responds with "ZD 40000CB", a software-generated response that does not indicate the actual frequency of the sensor.

Z1 RESPONSE

ZXYZZZZZHH

X Sensor status
- P - Pass BIT
- F - Fail BIT
- D - Recent deice command

Y Fail code (displayed only if sensor status = F)
- 1 - Probe Failure
- 2 - Probe Deicing Heater Failure
- 3 - Electronics Failure

ZZZZZ Normalized frequency between 38,400 and 40,100

HH Checksum value (hexadecimal)

Figure 11.4.3. Format of Z1 (Send Routine Data) Response

11.4.3.4 **Z3XX Request (Perform Deice Cycle)**. This command causes the freezing rain sensor to initiate a deice cycle. The probe and strut heaters are activated for 1 to 60 seconds as determined by the number typed after "Z3". All communication with the sensor is locked out for 2 minutes following a Z3 command. The operator should wait for at least 5 minutes before attempting any other command.

WARNING

Serious injury could result if the probe is contacted within 30 minutes after issuing the Z3 command. Do not touch the probe for 30 minutes after issuing the Z3 command.

The sensor responds to a Z3 command with "ZDOKHH". "OK" indicates that sensor heaters are operating satisfactorily, and "HH" is a checksum value. The heater did not turn on properly if the sensor does not respond. If "OK" indication is not received, a Z4 command should be issued to determine if the heater failed.

The probe assembly becomes hot following a Z3 command; therefore personnel should wait at least 30 minutes after the command before touching the probe assembly. The heat generated in response to a Z3 command may damage the probe assembly, especially if the ambient temperature is above the sensor normal operating range. For this reason, the following guidelines must be followed when turning the heater on using the Z3 command.

Temperature Range	Duration
Below 5°C (41°F)	Do not turn heater on for more than 45 seconds.
Between 5 and 15°C (41 and 59°F)	Do not turn heater on for more than 5 seconds.
Above 15°C (59°F)	Do not turn heater on.

11.4.3.5 **Z4 Request (Perform Extended Diagnostics)**. The Z4 command causes the freezing rain sensor to perform an on-demand self-test. The test performed is an extended version of the test regularly performed with the Z1 command. Specifically, the Z4 command performs a more detailed check of the sensor memory circuits and exercises more of the heater circuitry. The format for the Z4 response is "ZXYHH". "X" represents sensor status (P, F, or D), "Y" is the fail code (1, 2, or 3), and "HH" is the checksum value.

11.4.3.6 **F5 Request (Field Calibration)**. The F5 command causes the freezing rain sensor to perform an automatic calibration. Sensor calibration is not a periodic task and is not authorized for field use. Calibration is performed only at the National Reconditioning Center (NRC) after replacing the probe assembly, electronics processor board, or if frequency is outside the range of 39,990 to 40,010 Hz. Calibration is performed only when the probe is clean and dry and environmental conditions are acceptable.

The format of the sensor's response to the F5 command is "ZXYZZZZZ". "X" indicates sensor status (P or F), "Y" is the fail code (1, 2, or 3), and "ZZZZZ" is the calibration frequency. The calibration frequency must be between 39,900 and 40,100 hertz. A failure is indicated if the calibration frequency is outside these limits. After issuing the F5 command, the maintenance technician must wait at least 3 minutes before issuing any other command and the calibration frequency must be 40,000 ±10 Hz.